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Document de Travail
Working Paper

Lemna

EA 4272

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2010/19

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Testing the Martingale Difference Hypothesis in the EU ETS Markets for the CO_2 Emission Allowances: Evidence from Phase I and Phase II*

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*The authors would like to thank the Conseil Français de l'Energie for their financial support of this research.

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Abstract

This study examines the martingale difference hypothesis (MDH) for the market of carbon emission allowances within the European Union Emission Trading Scheme (EU ETS) during the Phase I and the Phase II, using both daily and weekly data over the period 2005–2009. The weak-form efficient market hypothesis for spot prices negotiated on BlueNext, European Energy Exchange and NordPool is tested with new variance ratio tests developed by Kim (2009). For the Phase I, the results show that these three markets of the European Union allowances seems to be efficiency, except after the European Commission announcements of stricter Phase II allocation in October 2006. Finally, we find that the CO_2 spot prices seem to be weak-form efficiency during the Phase II since the MDH is failed to reject from both daily and weekly data.

Keywords: CO_2 emission allowances; market efficiency; martingale difference hypothesis; variance ratio test.

JEL Classification: G14; Q53; C14.

1 Introduction

The Kyoto protocol is designed to cut six major greenhouse gases (GHGs) emission, particularly carbon dioxide (CO_2)[1] by making the polluter start paying for climate change. Most countries have signed and ratified the Kyoto protocol to the Union Nation Framework Convention on Climate Change.[2] The protocol is based on a "cap and trade" system. Each country is agreed with the intention of reducing their overall emissions by 8% of their 1990 levels by the end of 2012. For the 5-years compliance period from 2008 until 2012, entities (nations or companies) that emit less than their quota are able to sell emission credits to entities that exceed their quota. It is also possible to sponsor carbon projects that provide a generating tradable carbon credits. To aid countries in achieving their reduction objectives, the Protocol includes three flexibility mechanisms: the creation of an international carbon market, Joint Implementation and the Clean Development Mechanism.[3]

Several national and regional emission markets have been established in which a variety of specialized financial instruments are traded. Europe has emerged as a leader in the emissions trading industry with the European Union Emission Trading Scheme (EU ETS) being the world's largest single market for CO_2 emission allowances, which covers up to 40% of European CO_2 emissions. Indeed, the EU ETS markets are the largest, most liquid and most developed. Its main objective consists in giving incentives to industrials to reduce emissions and to contribute to the promotion of low carbon technologies and energy efficiency among CO_2 emitting plants. Most important combustion entities manage their compliance between their allocation and

[1] The CO_2 belongs to the GHG group with the methane CH_4, nitrous oxide N_2O, hydroflurocarbons HFC_s, perfluorocarbons PFC_s and sulphur hexafluoride SF_6.

[2] In October 16, 2008, 183 countries had signed and ratified the Kyoto protocol. The United States is the only country why has not ratified the protocol.

[3] Joint Implementation (JI) projects do not create credits, but rather transfer reduction units from one country to another. The aim of Clean Development Mechanism (CDM) projects is to promote investments in developing countries by industrialized nations and to encourage the transfer of low-emission technologies.

annual verified emissions by buying or selling European Union Allowances (EUAs) to emit a ton of carbon.

The EU ETS was initiated in January 2005 as the central framework that EU member states should employ in order to fulfill their obligations under the Kyoto protocol, i.e., to reduce the anthropogenic contribution of the greenhouse gas emissions (primarily CO_2) in the atmosphere. The EU ETS has been designed to operate in two initial phases. The first phase (2005–2007, Phase I) is a pilot phase during which the trading volume increased from 262 million metric tons in 2005 to 818 million metric tons in 2006 to 1.4 billion in 2007. The value of trades reached 30 billion euros in 2007. Phase I established a strong carbon market and provided new business development opportunities for risk management and market operators. The second phase (2008–2012, Phase II) coincides with the period when the EU must meet the 8% decrease from 1990 levels under the Kyoto Protocol. For the post-2012 period, the European Commission has decided to continue the operation of the market with the EU member states having already agreed to reduce up to 2020 their greenhouse gas emissions by an additional 12% over the obligatory levels under the Kyoto protocol.[4] In order to improve the fluidity of the EU ETS, organized allowance trading has been segmented across trading platforms: European Climate Exchange (ECX) based in London and Amsterdam started in April 2005, Nordic Power Exchange (Nord Pool) in Norway began in February 2005, BlueNext in France started in June 2005[5], European Energy Exchange (EEX) in Germany began in March 2005, Energy Exchange Austria (EEA) in Austria began in June 2005, and SendeCO2 in Spain started at the end of 2005.

Several relevant research papers have been published in the economics literature on the emission allowance market mechanisms, policies and their implications.[6] Recently, a growing empirical research has been undertaken from a financial market framework,

[4]See Daskalakis and Markellos (2008) for a discussion on the EU ETS.

[5]Powernext Carbon became BlueNext on January 2008

[6]See, for example, Rubin (1996), Kling and Rubin (1997), Boemare and Quirion (2002), Kosobud, Stokes and Tallarico (2002), Svendsen and Vesterdal (2003), Vesterdal and Svendsen (2004), Böhringer and Lange (2005), Ellerman (2005) and Ellerman, Buchner and Carraro (2007), Stern (2007), and the Special issue in *Oxford Review of Economic Policy*, (2008, Volume 24, Number 2), among others.

especially on the behavior of emission allowance spot and futures prices, e.g., Alberola et al. (2008), Daskalakis and Markellos (2008), Paolella and Taschini (2008), Seifert et al. (2008), Benz and Trück (2009), and Boutaba (2009).[7]

An important question is whether the chosen mechanics of the EU ETS have allowed the market to operate efficiently during the Phase I (2005–2007) and since implementing the Phase II (2008–2012). In other words, do emission allowance prices reflect all available information to the extent that no investor can systematically gain excess returns (see, Fama, 1970, 1991, 1998; Fama and French, 1988; Lo and MacKinlay, 1988; among others)? Investigating this issue is crucial, since the prime aim of the EU ETS is to allow the participating countries to achieve environmental compliance in a cost-effective and economically optimal manner, both of which implicitly require that the market itself is efficient. The efficiency of the CO_2 market is particularly important for emission intensive firms, policy makers, risk managers and for investors in the emerging class of energy and carbon hedge funds. Carbon market efficiency as the objective of carbon markets is to enable firms to achieve their emissions reductions at minimum cost. If markets are inefficient the policy implications are that there is a greater role for regulation to improve information flows and reduce market manipulation.

Since the seminal papers of Samuelson (1965) and Fama (1965), the efficient market hypothesis (EMH thereafter) states that efficient market prices follow a random walk or a martingale[8], and always fully and instantaneously reflect all available and relevant information, where the information set consists of past prices and returns. As a result, future prices are purely unpredictable based on past price information and fluctuate only in response to the random flow of news (Fama, 1970; 1991). Moreover,

[7]Some others papers focused on the relationship between spot and futures markets for EUAs, e.g., Uhrig-Homburg and Wagner (2007), Milunovich and Joyeux (2007), Trück et al. (2007), Alberola and Chevallier (2009), Daskalikas et al. (2009).

[8]The terms "random walk" and "martingale" have been interchangeably used in the literature. However, strictly speaking, the innovations series is $i.i.d.$ for "random walk", while it is a martingale difference sequence for "martingale". See Escanciano and Lobato (2009) for a discussion.

since price adjustment to a new piece of information is instantaneous and accurate, returns cannot be predicted. This means that historical prices cannot be used to form superior forecasts or to accomplish trading profits above the level justified by the risk assumed. Most of the EMH studies on financial markets tested for the weak-form efficiency through the martingale difference hypothesis (MDH thereafter)[9], where the current price is the best predictor of the future price and the returns are independent (or uncorrelated) with the past values. If the CO_2 spot price follows a martingale difference sequence (MDS thereafter), then the market is weak-form efficient, and hence not predictable. This means that it is impossible for a trader to gain excess returns over time through speculation. If the spot price is predictable, then the market is not weak-form efficient. This means that the traders can generate abnormal returns through speculation. For these reasons, the predictability of return is an important issue to this concerned with carbon market efficiency. Nevertheless, little attention has been devoted on the weak-form efficiency in the CO_2 markets. Seifert et al. (2008) showed that the daily CO_2 spot price negotiated on BlueNext from June 24, 2005 to December 15, 2006, seems to be relatively efficient, using autocorrelation tests. Daskalakis and Markellos (2008) assessed the weak-form efficiency by analyzing spot and futures market data from BlueNext, Nord Pool and ECX, using daily prices covering the period from the first available quote up to December 12, 2006. They found that BlueNext and Nord Pool markets are not consistent with weak-form efficiency from variance ratio tests and technical analysis trading rules.

In this paper we extend the examination of the weak-form EMH in the EU ETS markets for CO_2 emission allowances in two ways. First, this study is based on a more extensive sample. We study daily data for three spot markets, BlueNext, EEX and NordPool, during the Phase I (2005–2008) and the Phase II (2008–2009) in order to compare the evolution between the two initial phases and these markets. We also investigate the EMH over various sub-periods in order to analyze the effects of the

[9] Note that if the MDH is based on the theory of efficiency, the EMH does not imply that prices follow a martingale difference sequence (MDS). Therefore, if prices do not follow a MDS, this does not imply inefficiency of the market. See Lo and MacKinlay (2001) for a discussion on MDH and EMH.

important structural change due to the first disclosure of 2005 verified emissions on April 2006 revealing the long position of each plant which was accompanied by a sudden allowance price collapse, as well as the European Commission announcements of stricter National Allocation Plans II validation in October 2006 which reinforced the depressive effect on prices. Furthermore, we analyze the weekly data for the three spot markets in order to consider a market as perfectly weak-form efficient if it is found to behave randomly at any level of data frequency. This avoids the shortcomings with the high and medium/low frequency data (e.g., non-trading, bid-ask spread, asynchronous prices). Second, the weak-form EMH is evaluated from powerful method, namely the variance-ratio [VR] test.[10] More precisely, we apply the bootstrapped automatic VR test suggested by Kim (2009). This VR test is robust to heteroscedasticity and non-normality which are present in CO_2 emission allowance prices (e.g., Milunovich and Joyeux, 2007; Daskalakis and Markellos, 2008; Benz and Trück, 2009) and is powerful in small finite sample.

The remainder of this paper is organized as follows: Section 2 presents the bootstrapped automatic VR test; Section 3 summarizes the characteristics of the data, and the empirical results on the MDH are given in Section 4. The conclusion is drawn in Section 5.

2 Variance ratio tests

Since the seminal work of Lo and MacKinlay (1988, 1989) and Poterba and Summers (1988), the standard variance ratio [VR] test or its improved modifications have been widely used for testing market efficiency, including the multiple variance ratio test of Chow and Denning (1993), sign and rank tests of Wright (2000), wild bootstrap test of Kim (2006), and power-transformed test of Chen and Deo (2006).[11]

[10] Lo and MacKinlay (1989) examined the VR, Dickey-Fuller unit root and Box-Pierce serial correlation tests and found that VR test was more powerful than the others under the heteroscedastic random walk.

[11] See Hoque, Kim and Pyun (2007) and Charles and Darné (2009) for a review.

The VR test is based on the property that, if return is purely random, the variance of k-period return (or k-period differences), $y_t - y_{t-k}$, of the time series y_t, is k times the variance of the one-period return (or the first difference), $y_t - y_{t-1}$. Hence, the VR at lag k, $VR(k)$, defined as the ratio of $1/k$ times the variance of k-period return to that of one-period return, should be equal to one for all values of k.

The VR test evaluates the hypothesis that a given time series or its first difference (or return), $x_t = y_t - y_{t-1}$, is a collection of independent and identically distributed observations (i.i.d.) or that it follows a MDS. Define the VR of k-period return as

$$\begin{aligned} V(k) &= \frac{Var(x_t + x_{t-1} + \cdots + x_{t-k+1})/k}{Var(x_t)} \\ &= \frac{Var(y_t - y_{t-k})/k}{Var(y_t - y_{t-1})} = 1 + 2\sum_{i=1}^{k-1}\left(\frac{(k-i)}{k}\right)\rho_i \end{aligned}$$

where ρ_i is the i-th lag autocorrelation coefficient of $\{x_t\}$. $V(k)$ is a particular linear combination of the first $(k-1)$ autocorrelation coefficients, with linearly declining weights. The central idea of the variance ratio test is based on the observation that when returns are uncorrelated over time, we should have $Var(x_t + \cdots + x_{t-k+1}) = kVar(x_t)$, i.e. $V(k) = 1$.

A test can be constructed by considering the statistic based on an estimator of V(k). Following Wright (2000), the VR statistic can be written as

$$VR(x;k) = \left\{(Tk)^{-1}\sum_{t=k}^{T}(x_t + \cdots + x_{t-k+1} - k\hat{\mu})^2\right\} \div \left\{T^{-1}\sum_{t=1}^{T}(x_t - \hat{\mu})^2\right\} \tag{1}$$

where $\hat{\mu} = T^{-1}\sum_{t=1}^{T} x_t$. If the return follows a MDS, the expected value of $VR(x;k)$ should be equal to unity for all horizons k. Lo and MacKinlay (1988) proposed the asymptotic distribution of $VR(x;k)$. Moreover, Cochrane (1988) showed that the estimator of $V(k)$ can be interpreted in terms of the frequency domain. This estimator which uses the usual consistent estimators of variance is asymptotically equivalent to 2π the normalized spectral density estimator at the zero frequency.

To implement the test, one should test for the null hypothesis that the VR is equal to one for a set of (holding periods) k values. For example, popular choices in empirical applications include $k \in \{2, 5, 10, 30\}$ for daily return, while $k \in \{2, 4, 8, 16\}$ for weekly return (see, for example, Belaire-Franch and Opong, 2005; and Fong et al., 1997). However, these choices are entirely arbitrary and adopted without any concrete statistical justifications. In view of this, Choi (1999) proposed an automatic variance ratio (AVR, thereafter) test, in which the optimal value of holding period k is determined automatically using a completely data-dependent procedure.

Let x_t denote asset return at time t, where $t = 1, ..., T$. Choi's (1999) AVR test is based on a VR estimator related to the normalized spectral density estimator at zero frequency, namely,

$$\widehat{VR}(k) = 1 + 2 \sum_{i=1}^{T-1} h(i/k)\widehat{\rho}(i), \tag{2}$$

where $\hat{\rho}(i) = \hat{\gamma}(i)/\hat{\gamma}(0)$ is the sample autocorrelation of order i, $\hat{\gamma}(i)$ is the sample autocovariance of order i, and $h(x)$ is the quadratic spectral kernel defined as

$$h(x) = \frac{25}{12\pi^2 x^2} \left[\frac{\sin(6\pi x/5)}{6\pi x/5} - \cos(6\pi x/5) \right],$$

According to Choi (1999), under the condition that x_t is is serially uncorrelated,

$$AVR(k) = \sqrt{T/k}[\widehat{VR}(k) - 1]/\sqrt{2} \rightarrow_d \mathbf{N}(0, 1), \tag{3}$$

as $T \to \infty$, $k \to \infty$, and $T/k \to \infty$, when x_t is an $i.i.d.$ sequence with finite fourth moment. To test for $H_0 : VR(k) = 1$, a choice for the value of lag truncation point k should be made, which is equivalent to the value of holding period in the time domain. Choi (1999) proposed a data-dependent method of choosing k optimally, following Andrews (1991). The AVR test statistic with the optimally chosen lag truncation point is denoted as $AVR(k^*)$. The $AVR(k^*)$ test is an asymptotic test which may show deficient small sample properties, especially under conditional heteroscedasticity. When x_t is subject to conditional heteroscedasticity, Kim (2009) suggested to employ the wild bootstrap of Mammen (1993) to improve small sample properties, as in Kim (2006) who applied the wild bootstrap to the Lo-MacKinlay and Chow-Denning tests.

Kim's (2009) wild bootstrap AVR test is conducted in three stages as follows:

1. Form a bootstrap sample of size T as $x_t^* = \eta_t x_t$ $(t = 1, ..., T)$ where η_t is a random variable with zero mean and unit variance;

2. Calculate $AVR^*(k^*)$, the $AVR(k^*)$ statistic calculated from $\{x_t^*\}_{t=1}^T$;

3. Repeat 1 and 2 B times, to produce the bootstrap distribution of the AVR statistic $\{AVR^*(k^*; j)\}_{j=1}^B$.

The test for H_0 against the two-tailed alternative is conducted to using the p-value, which is estimated as the proportion of the absolute values of $\{AVR^*(k^*; j)\}_{j=1}^B$ greater than the observed statistic $AVR(k^*)$. Alternatively, one may use the $100(1-2\alpha)$ per cent confidence interval $[AVR^*(\alpha), AVR^*(1-\alpha)]$, where $AVR^*(\alpha)$ denotes the α^{th} percentile of $\{AVR^*(k^*; j)\}_{j=1}^B$. As advocated by Kim (2009), the number of bootstrap iterations is set to 500.

Kim (2009) found that the wild bootstrap AVR significantly improves the size and power properties of the AVR test. Furthermore, this wild bootstrap AVR test compares favorably to the other alternatives such as the wild bootstrap Chow-Denning test of Kim (2006), the power-transformed test of Chen and Deo (2006) and the joint sign test of Kim and Shamsuddin (2008), where the choice of holding periods k is arbitrarily made.

3 Data description

The spot data of the study consists of the daily closing prices for EUA negotiated on BlueNext, EEX and Nordpool. For the Phase I, the dataset covers the period from June 24, 2005 to April 25, 2008 (708 observations) for BlueNext, August 04, 2005 to March 20, 2008 (664 observations) for EEX, and October 25, 2005 to March 31, 2008 (610 observations) for NordPool. For the Phase II, they cover the period from February 26, 2008 to November 11, 2009 (435 observations) for BlueNext, January 16, 2009 to November 11, 2009 (209 observations) for EEX, and April 15, 2008 to November 11, 2009 (395 observations) for NordPoll. Figures 1 and 2 provide a graphical representation of these series. We also examine the weekly spot data where the prices are observed on Wednesday or on the next day if the markets are closed on Wednesday. We use the both frequencies to overcome issues like biasness with daily and weekly data (e.g., non-trading, bid-ask spread, asynchronous prices).

Table 1 presents summary statistics for the returns calculated as the first differences in the logs of the EUA prices. During the Phase I, the CO_2 markets display negative mean returns of about -0.01% per day whereas during the Phase II the mean returns are very low ($\pm 0.001\%$). Note that the risk measured as the standard deviation is higher for the Phase I (close to 0.100) than that for the Phase II (close to 0.030). All the returns are highly non-normal, i.e. showing evidence of significant excess skewness and excess kurtosis during the Phase I, as might be expected from daily returns. Note that there is no evidence of excess skewness during the Phase II. Moreover, the kurtosis is significant and very high for the Phase I, implying that the distribution of the returns is leptokurtic and thus the variance of the CO_2 spot prices is principally due to infrequent but extreme deviations. A leptokurtic distribution has a more acute peak around the mean and fat tails. The Lagrange Multiplier test for the presence of the ARCH effect indicates clearly that the prices show strong conditional heteroscedasticity, which is a common feature of financial data. In other words, there are quiet periods with small prices changes and turbulent periods with large oscillations.

For the weekly data (Table 1), the returns show the same characteristics than those for the daily data. Note that NordPool for the Phase I and EEX for the Phase II do not exhibit conditional heteroskedasticity.

4 Testing the efficient market hypothesis

We investigate the weak-form EMH for BlueNext, EEX and Nordpool by testing the MDH from wild bootstrapped AVR test. The Table 2 displays the results for daily (Panel A) and weekly (Panel B) data during the Phase I and the Phase II. The results show that the MDH is rejected for EEX at the level 5% and for BlueNext and NordPool at the level 10% whereas the results are consistent with the MDS in the EUAs spot

Table 1: Statistical analysis of returns

Market	Obs.	Mean	SD	Skewness	Kurtosis	ARCH(10)
				Daily		
Phase I						
BlueNext	707	-0.011	0.096	-0.669[a]	18.876[a]	37.583[a]
EEX	663	-0.010	0.125	0.726[a]	18.857[a]	54.682[a]
NordPool	609	-0.011	0.121	-0.176	29.321[a]	51.361[a]
Phase II						
BlueNext	434	-0.001	0.028	-0.125	4.346[a]	34.332[a]
EEX	208	0.001	0.031	0.166	4.007[a]	25.608[a]
NordPool	394	-0.002	0.029	0.020	4.630[a]	18.705[a]
				Weekly		
Phase I						
BlueNext	146	-0.054	0.161	-1.351[a]	6.320[a]	10.286
EEX	134	-0.052	0.212	-0.621[a]	8.531[a]	59.103[a]
NordPool	124	-0.062	0.171	-1.191[a]	5.605[a]	9.773
Phase II						
BlueNext	88	-0.004	0.064	-0.424	4.437[a]	31.114[a]
EEX	41	0.004	0.072	-0.316	3.949[a]	13.992
NordPool	80	-0.007	0.067	-0.430	4.543[a]	29.529[a]

Notes: The skewness and kurtosis statistics are standard-normally distributed under the null of normality distributed returns. ARCH(10) indicates the Lagrange multiplier test for conditional heteroscedasticity with 10 lags. [a] means significant at the levels 5%.

prices during the Phase II for the three markets from the daily data. These results are confirmed from the weekly data. The finding on the Phase I confirms that of Daskalakis and Markellos (2008) for BlueNext and NordPool on a shorter period. Therefore, it seems that CO_2 spot markets for BlueNext, EEX and NordPool can be considered perfectly weak-form efficient during the Phase II because they behave randomly at all levels of data frequency.

We re-examine the weak-form EMH during the Phase I for the three markets due to the presence of a structural break[12] on the April 25, 2006 which can biased

[12]The structural break has been detected using the Bai and Perron (1998, 2003) tests.

Table 2: Results of AVR* tests for Phase I and Phase II.

	BlueNext	EEX	NordPool
		Daily	
Phase I	-3.154^b (0.072)	-3.555^a (0.047)	-3.640^b (0.059)
Phase II	0.437 (0.583)	0.689 (0.446)	0.566 (0.497)
		Weekly	
Phase I	1.908^a (0.035)	2.373^b (0.057)	2.021^b (0.056)
Phase II	0.064 (0.827)	-0.185 (0.675)	0.043 (0.877)

[a] and [b] Significant at the levels 5% and 10%, respectively. We report the VR statistic for each test. Phase I covers the period from June 24, 2006 to April 25, 2008, and Phase II covers the period from February 26, 2008 to September 22, 2008.

the VR tests (Lee and Kim, 2006). Indeed, the first disclosure of 2005 verified emissions on April 2006 revealing the long position of each plant was accompanied by a sudden allowance price collapse (more than 50%).[13] On the May 15, 2006 the European Commission confirmed verified emissions were about 80 million tons or 4% lower than yearly allocation. This break highlights that when the cap is not set below business-as-usual emissions, allowance trading does not necessarily guarantee a carbon price high enough to provide incentives to reduce CO_2 emissions since the stringency of the cap did not appear sufficient for market agents, and consequently the allowance price collapsed (Alberola et al., 2008). Furthermore, from October 2006 to the end of 2007 CO_2 prices tend towards zero following the European Commission (EC) announcement of stricter National Allocation Plans (NAPs) II validation, until the end of Phase I. This price pattern suggests that allowance trading was based on heterogeneous anticipations prior to information disclosure. Among the main explanations of low allowance prices towards the end of Phase I, previous literature identifies over-allocation concerns, early abatement efforts in 2005 due to high

[13] Beginning at 8 euros on January 1, 2005 EUA prices rose to 25–30 euros until the end of April. On the last week of April 2006 prices collapsed when operators disclosed 2005 verified emissions data and realized the scheme was oversupplied. After this considerable adjustment by 54% in four days, EUA prices moved in the range from 15 euros to 20 euros until October 2006.

allowance prices, and possibly decreasing abatement costs in 2006 due to abnormal temperatures and switching from coal- to gas-fired electricity in a context of falling natural gas prices compared to coal (Ellerman and Buchner, 2008; Mansanet-Bataller et al., 2007; Alberola et al., 2008; Hintermann, 2010). Alberola and Chevallier (2009) suggested that low allowance prices may also be explained by banking restrictions between 2007 and 2008. Given the impossibility of using Phase I allowances in Phase II (no bankability), the overall excess in allowances led to a decrease in their price which finally dropped to zero.[14]

Therefore, we investigate the effects of these events on the efficiency of the EUAs spot market during the Phase I, by re-running the VR tests for the following subperiods: Beginning of the spot price negociations (2005) [BSPN05] to April 24, 2006, and April 25, 2006 to the end of the spot price negociations (2008) [ESPN08], namely before and after the compliance break, as well as April 25, 2006 to October 26, 2006 to ESPN08, namely before and after the EC announcement of stricter NAPs II.

Table 3 displays the results of bootstrapped AVR tests on the sub-periods for daily data (Panel A) and weekly data (Panel B). The structural change due to the first disclosure of 2005 verified emissions on April 2006 does not seem to have an impact on the weak-form efficiency since the test statistics are significant at the levels 5% or 10% for the three markets from the daily data. Nevertheless, the MDH is rejected before the compliance break from the weekly data.

The EC announcement of stricter Phase II allocation appears to have a negative effect on the EUAs spot markets since after this announcement in October 2006. The CO_2 spot prices in BlueNext, EEX and Nordpool are not coherent with the MDS at the level 5% from both daily and weekly data. This indicates that before October 2006 the daily data reflected the most up-to-date information about CO_2 spot prices, and thus it is impossible for a trader to generate excess returns over time through speculation. However, there was possibility of abnormal returns through speculation after October 2006.

[14]See Hintermann (2010) for a discussion on the allowance price drivers in the Phase I of the EU ETS.

Table 3: Results of AVR* tests in Phase I sub-periods.

	BlueNext	EEX	NordPool
		Daily	
Compliance break			
BSPN05 – April 2006	3.077^a (0.006)	1.948^b (0.077)	2.208^b (0.062)
April 2006 – ESPN08	-3.414^a (0.027)	-3.407^a (0.026)	-3.685^a (0.039)
Stricter NAPs II			
April 2006 – Oct 2006	0.034 (0.955)	−0.662 (0.665)	−0.023 (0.954)
Oct 2006 – ESPN08	-3.043^a (0.039)	-2.908^a (0.043)	-3.120^a (0.033)
		Weekly	
Compliance break			
BSPN05 – April 2006	−0.009 (0.935)	0.001 (0.995)	−0.424 (0.334)
April 2006 – ESPN08	2.000^a (0.020)	2.024^b (0.092)	2.244^a (0.028)
Stricter NAPs II			
April 2006 – Oct 2006	0.357 (0.637)	0.457 (0.556)	0.416 (0.466)
Oct 2006 – ESPN08	1.617^a (0.035)	2.211^a (0.019)	1.911^a (0.023)

^{a} and ^{b} Significant at the levels 5% and 10%, respectively. We report the VR statistic for each test. BSPN05: Beginning of the spot price negociations (2005); ESPN08: End of the spot price negociations (2008).

5 Conclusion

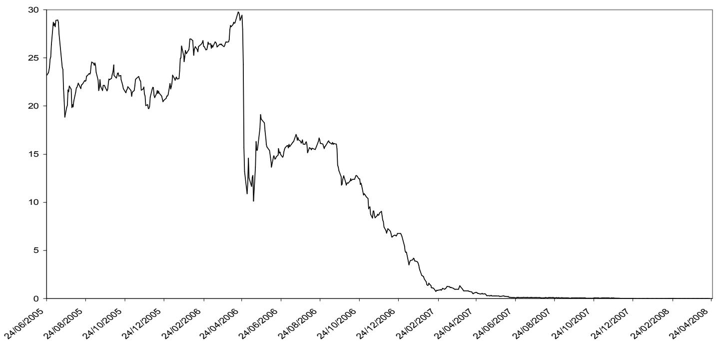
This paper explored the weak-form efficiency in the EU ETS markets for carbon emission allowances, using both daily and weekly spot prices negotiated on BlueNext, EEX and Nordpool, during the Phase I and Phase II. For that, we used new variance ratio tests, which are robust to heteroscedasticity and non-normality – present in EUAs spot prices – and powerful in small sample, namely the bootstrapped automatic VR tests developed by Kim (2009).

For the Phase I, the results showed that these three markets of the EUAs seems to be efficiency, except after the European Commission announcements of stricter Phase II allocation in October 2006, suggesting the possibility of abnormal returns through speculation. Note that the first disclosure of 2005 verified emissions implying a sudden allowance price collapse in April 2006 did not appear to affect the efficiency. Finally, we found that the CO_2 spot prices seem to be weak-form efficiency during the Phase II since the MDH is failed to reject from both daily and weekly data.

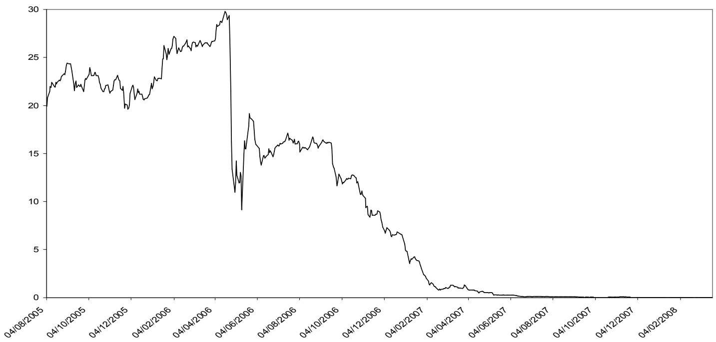
Daskalakis and Markellos (2008) argued that allowing for short selling and for allowance banking between successive phases may increase liquidity and improve the efficiency of the market. It is imperative that policy makers address these issues during the eminent reviewing process, in order to ensure that the EU ETS evolves into a mature, efficient and internationally competitive market.

Further research should investigate the weak-form efficiency on the futures markets.

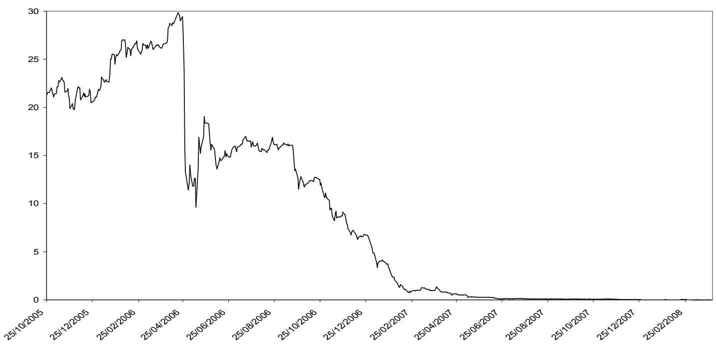
Figure 1: Daily spot prices during Phase I



(a) BlueNext

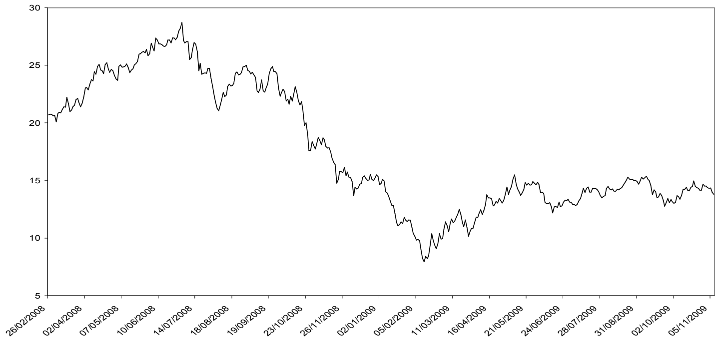


(b) EEX

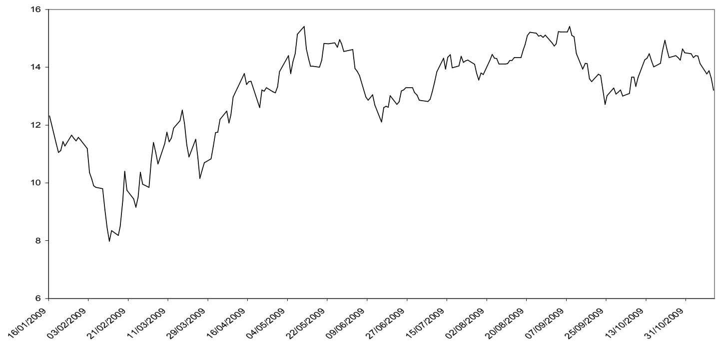


(c) NordPool

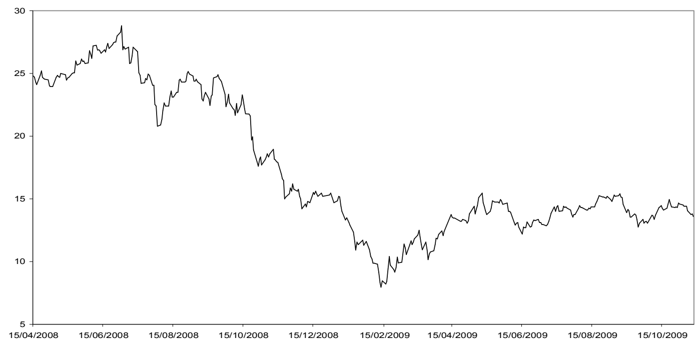
Figure 2: Daily spot prices during Phase II



(a) BlueNext



(b) EEX



(c) NordPool

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